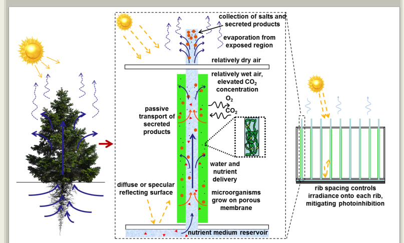
Center Innovation Fund: ARC CIF

Novel Photobioreactor Development for Space Applications (SABR)

Completed Technology Project (2011 - 2012)

Project Introduction

Capability for controlled and efficient cultivation of microbial cells in microgravity environments opens the possibility for a plethora of applications. One such application is the engineering of fully regenerative life support systems based on cultivation of photosynthetic microorganisms capable of utilizing waste streams and producing O2 and food for long duration manned space missions. This study presents a novel platform, called Surface-Adhering Bioreactor (SABR), which uses evaporation and capillary phenomena to deliver nutrients and remove metabolites to and from the microbial cells enabling efficient operation in microgravity environment. Long term support of humans in space currently depends on transport of consumables from Earth, with the International Space Station (ISS) being the primary example. Aboard the ISS, oxygen for human respiration is generated by purifying water and then splitting water into oxygen and hydrogen by electrolysis. Meanwhile, carbon dioxide produced by human respiration is scrubbed from the cabin air, concentrated, and emitted from the shuttle. Furthermore, food is uploaded from Earth and solid waste is not reused. Therefore, current life support for humans in space depends on open loop technology, which in turn relies on access to supplies from Earth. This open loop technology requires periodic uploads and limits mission duration. Long term human-occupied missions must therefore seek closed loop life support. The Micro-Ecological Life Support System Alternative (MELiSSA) project, initiated by the European Space Agency in 1989, aimed to engineer a closed loop system consisting of five microbial compartments to completely recycle carbon, hydrogen, oxygen, nitrogen, sulfur, and phosphorous between the compartments and the human-occupied cabin. In addition, a subproject of MELiSSA, named BIORAT, aimed to use a centrifugal planktonic photobioreactor (PBR) to consume CO2 and generate O2 for a simulated human crew of two mice. A 5.6 L centrifugal air-lift photobioreactor successfully supported the two mice for the entire testing period of three weeks. However, the microorganisms in the BIORAT system are cultivated in a liquid medium with a dry weight density on the order of 1 g/L; roughly one kilogram of water is needed to cultivate one gram of biochemically active biomass. The water intensity of such a system is a potential problem for space exploration where mass is an important constraint. The power consumption of a centrifugal reactor is also a concern. In light of these challenges, we designed and prototyped a novel platform where microorganisms grow in densely packed biofilms (benthic) on microporous substrates rather than in suspension (planktonic). Furthermore, nutrient medium is passively delivered to the biofilms by evaporation and capillary forces. This makes gas and nutrient delivery independent of inertial and gravitational forces, as opposed to the centrifugal air lift photobioreactor component of the BIORAT system. We then operated a scaled down prototype to cultivate the cyanobacterium Anabaena variabilis. A conventional planktonic photobioreactor of similar size was also operated for comparison. The SABR exhibited growth rates four times greater than growth rates in a conventional planktonic photobioreactor, using 25 times less water. In addition to hosting



By utilizing evaporation and capillary forces, the SABR, or "synthetic tree," mimics the natural process of transpiration in higher plants.

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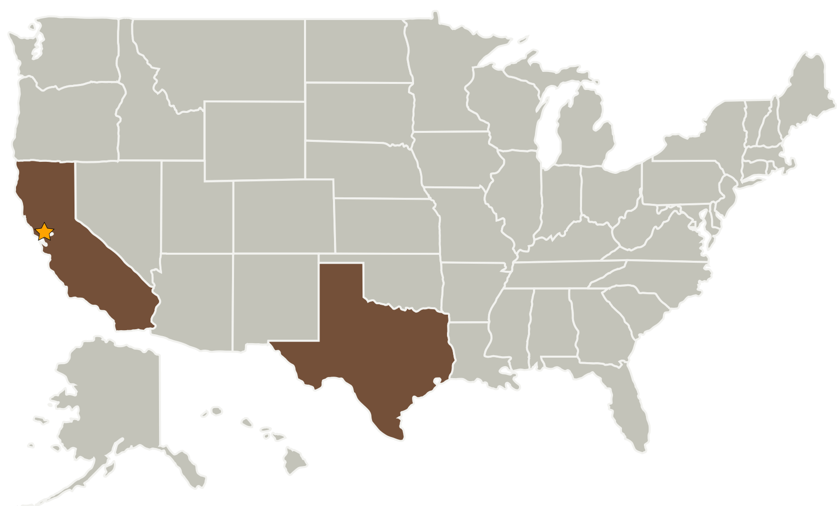
photosynthetic microbes, the SABR can provide a shear-free growth environment for mammalian tissue cells, cells of pharmaceutical interest, and nitrogen fixing bacteria. It is expected that the SABR will be a versatile cultivation platform for constructing micro-ecosystems in space for human life support.

Anticipated Benefits

This project provides a microbial cultivation platform that enables closed loop life support for long duration space missions.

Primary U.S. Work Locations and Key Partners



Organizations Performing Work	Role	Type	Location
★Ames Research Center(ARC)	Lead Organization	NASA Center	Moffett Field, California
The University of Texas at Austin	Supporting Organization	Academia	Austin, Texas

Primary U.S. Work Locations	
California	Texas

Organizational Responsibility

Responsible Mission Directorate:

Space Technology Mission Directorate (STMD)

Lead Center / Facility:

Ames Research Center (ARC)

Responsible Program:

Center Innovation Fund: ARC CIF

Project Management

Program Director:

Michael R Lapointe

Program Manager:

Harry Partridge

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Leslie Prufert-bebout

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Leslie Prufert-bebout

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Brad M Bebout
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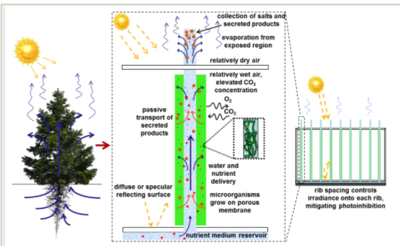
Images



Artificial transpiration mechanism in the Surface-Adhering BioReactor (SABR)
By utilizing evaporation and capillary forces, the SABR, or "synthetic tree," mimics the natural process of transpiration in higher plants.
(https://techport.nasa.gov/image/2782)

Stories

1676 Approval from Ames (#17536)
(https://techport.nasa.gov/file/8727)

Links

A novel microbial cell cultivation platform for space applications
(http://www.univelt.com/book=3900)

Technology Maturity (TRL)

Start: **2**
Current: **5**
Estimated End: **5**

1	2	3	4	5	6	7	8	9
Applied Research			Development			Demo & Test		

Technology Areas

Primary:

- TX06 Human Health, Life Support, and Habitation Systems
  - └ TX06.1 Environmental Control & Life Support Systems (ECLSS) and Habitation Systems
    - └ TX06.1.2 Water Recovery and Management